Answers to Teachers' Questions About the Next Generation Science Standards

Cindy Workosky and Ted Willard

K–12 teachers of science have been digging into the *Next Generation Science Standards (NGSS)* (NGSS Lead States 2013) to begin creating plans and processes for translating them for classroom instruction. As teachers learn about the *NGSS,* they have asked about the general structure of the standards document and how to read and use it. This article, part of a series about different aspects of the standards, answers some of the most common questions about the architecture of the *NGSS,* from deciphering the codes to understanding the boxes.

Q. What are the major components of the standards?

A. Generally speaking, there are four major components on every standards page (Figure 1, p. 30):

1. A code and title that describe the content of the standard;
2. A varying number of performance expectations that describe what students should be able to know and do at the end of instruction;
3. A foundation box that describes in more detail each of the three dimensions of the performance expectation; and
4. A connection box that includes connections to the standard from other disciplinary core ideas at the grade level and across grade levels and to the *Common Core State Standards* (*CCSS*) (NGAC and CCSSO 2010) in mathematics and English language arts and literacy.

Q. What exactly are performance expectations?

A. The standards include performance expectations that describe what students should be able to know and do at the end of instruction. This is very different from previous national and state standards that had separate inquiry and content goals. The performance expectations combine three key dimensions:

1. Science and engineering practices (how science is conducted in the real world—such as through planning and carrying out investigations);
2. Disciplinary core ideas (the content—for example, biology); and
3. Crosscutting concepts (ideas—such as cause and effect—that permeate all the sciences).

Performance expectations describe what is to be assessed at the *end* of instruction and guide the development of assessments. Teachers should not use the performance expectations as a curriculum. Instead, they should use their own professional judgment about how learning should take place in the classroom, keeping in mind what students should be able to do by the end of instruction, as described by the performance expectation.

Q. How does the foundation box support the performance expectations? What do I do with this content?

A. The foundation box provides a more complete description of the performance expectations. It describes the science and engineering practices, disciplinary core ideas, and crosscutting concepts used to make up a particular set of performance expectations. These are the "raw materials" that teachers can use to construct learning experiences for students.

Q. What do the colors represent?

A. The foundation box has three separate areas that are color coded. The blue area represents science and engineering

practices; the orange area is for disciplinary core ideas; and the green area is for crosscutting concepts. Sometimes, the text of performance expectations is color coded to indicate what part of the foundation box the text is based on.

Q: What is considered "the standard"? Is it the performance expectations or does it include the boxes below?

A. Different states have different legal definitions for what

FIGURE 1

A typical standards page.

HS.Weather and Climate

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Students who demonstrate understanding can:

HS-ESS2-4. **Use a model to describe how variations in the flow of energy into and out of Earth systems result in changes in climate.** [Clarification Statement: Examples of the causes of climate change differ by timescale, over 1-10 years: large volcanic eruption, ocean circulation; 10-100s of years: changes in human activity, ocean circulation, solar output; 10-100s of thousands of years: changes to Earth's orbit and the orientation of its axis; and 10-100s of millions of years: long-term changes in atmospheric composition.] [Assessment Boundary: Assessment of the results of changes in climate is limited to changes in surface temperatures, precipitation patterns, glacial ice volumes, sea levels, and biosphere distribution.]

HS-ESS3-5. **Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.** [Clarification Statement: Examples of evidence, for both data and climate model outputs, are for climate changes (such as precipitation and temperature) and their associated impacts (such as on sea level, glacial ice volumes, or atmosphere and ocean composition).] [Assessment Boundary: Assessment is limited to one example of a climate change and its associated impacts.]

The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s). • Use a model to provide mechanistic accounts of phenomena. (HS-ESS2-4) **Analyzing and Interpreting Data** Analyzing data in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. • Analyze data using computational models in order to make valid and reliable scientific claims. (HS-ESS3-5) **Connections to Nature of Science** **Scientific Investigations Use a Variety of Methods** • Science investigations use diverse methods and do not always use the same set of procedures to obtain data. (HS-ESS3-5) • New technologies advance scientific knowledge. (HS-ESS3-5) **Scientific Knowledge is Based on Empirical Evidence** • Science knowledge is based on empirical evidence. (HS-ESS3-5) • Science arguments are strengthened by multiple lines of evidence supporting a single explanation. (HS-ESS2-4), (HS-ESS3-5)	**ESS1.B: Earth and the Solar System** • Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual climate changes. (secondary to HS-ESS2-4) **ESS2.A: Earth Materials and Systems** • The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles. (HS-ESS2-4) **ESS2.D: Weather and Climate** • The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space. (HS-ESS2-4),(secondary to HS-ESS2-2) • Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. (HS-ESS2-4) **ESS3.D: Global Climate Change** • Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts. (HS-ESS3-5)	**Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-ESS2-4) **Stability and Change** • Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. (HS-ESS3-5)

Connections to other DCIs in this grade-band: **HS.PS3.A** (HS-ESS2-4); **HS.PS3.B** (HS-ESS3-5); **HS.PS3.D** (HS-ESS3-5); **HS.PS4.B** (HS-ESS2-4); **HS.LS1.C** (HS-ESS3-5); **HS.LS2.C** (HS-ESS2-4); **HS.ESS1.C** (HS-ESS2-4); **HS.ESS2.D** (HS-ESS3-5); **HS.ESS3.C** (HS-ESS2-4); **HS.ESS3.D** (HS-ESS2-4)

Articulation of DCIs across grade-bands: **MS.PS3.A** (HS-ESS2-4); **MS.PS3.B** (HS-ESS2-4),(HS-ESS3-5); **MS.PS3.D** (HS-ESS2-4),(HS-ESS3-5); **MS.PS4.B** (HS-ESS2-4); **MS.LS1.C** (HS-ESS2-4); **MS.LS2.B** (HS-ESS2-4); **MS.LS2.C** (HS-ESS2-4); **MS.ESS2.A** (HS-ESS2-4),(HS-ESS3-5); **MS.ESS2.B** (HS-ESS2-4); **MS.ESS2.C** (HS-ESS2-4); **MS.ESS2.D** (HS-ESS2-4),(HS-ESS3-5); **MS.ESS3.B** (HS-ESS3-5); **MS.ESS3.C** (HS-ESS2-4), (HS-ESS3-5); **MS.ESS3.D** (HS-ESS2-4),(HS-ESS3-5)

Common Core State Standards Connections:

ELA/Literacy –

RST.11-12.1	Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-ESS3-5)
RST.11-12.2	Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. (HS-ESS3-5)
RST.11-12.7	Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-ESS3-5)
SL.11-12.5	Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (HS-ESS2-4)

Mathematics –

MP.2	Reason abstractly and quantitatively.(HS-ESS2-4),(HS-ESS3-5)
MP.4	Model with mathematics. (HS-ESS2-4)
HSN-Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-ESS2-4),(HS-ESS3-5)
HSN-Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. (HS-ESS2-4),(HS-ESS3-5)
HSN-Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-ESS2-4),(HS-ESS3-5)

they consider a "standard." Some states, for example, consider a single performance expectation to be a standard. Other states may refer to an entire set of performance expectations (a topic) to be a standard. Still others may consider a set of performance expectations and the corresponding foundation box to be a standard. NSTA considers the content of the foundation boxes to be just as important as the performance expectations in planning curriculum, instruction, and assessment, so we consider the "standard" to be the performance expectations plus the material in the foundation box.

Q. Why are there two arrangements of the standards: one by disciplinary core idea and one by topic? Which arrangement is better for me to use?

A. Both in print and on the web, the standards are shown in two different arrangements. One arrangement (by disciplinary core idea) matches the organizational structure used by the writers of *A Framework for K–12 Science Education* (NRC 2012), a publication from the National Academies of Science that guided development of the *NGSS*. The other arrangement (by topic) matches the arrangement that was used by the educators who wrote the standards. Teachers can use either arrangement or make their own arrangements. In the elementary grades (K–5), the performance expectations are presented grade by grade. In middle school and high school, they are presented by grade bands (6–8 and 9–12). Beyond that, the standards do not specify any particular order or organization for their teaching.

Q. When designing instruction using a particular performance expectation, do I have to use the exact disciplinary core idea, practice, and crosscutting concept that make up the performance expectation?

A. Absolutely not. The performance expectations are not meant to prescribe what to do during instruction. Teachers have the freedom and professional responsibility to decide what learning experiences will be most effective in helping students achieve the outcomes described in the performance expectations. Furthermore, research indicates that students will learn best if they engage in multiple practices as they develop their understanding of core ideas and crosscutting concepts. Each lesson should be three dimensional, meaning that it should integrate at least one practice, core idea, and crosscutting concept. Teachers should develop a logical sequence of activities during instruction that will provide students the proper motivation to develop and use the practices, core ideas, and crosscutting concepts they are to learn.

Q. Some standards have a connection to the nature of science and to engineering, technology, and applications of science. How do those concepts get integrated into the standard?

A. Just as the practices, core ideas, and crosscutting concepts should be integrated in a way that fits them together naturally, the same approach should be used for the connections to the nature of science and to engineering, technology, and applications of science. The writers of the standards have identified some places where connections may work naturally, but teachers should look for other opportunities as well.

NSTA is dedicated to helping all teachers of science and school leaders better understand the important instructional shifts in the *NGSS* and translate them into classroom instruction. Whether you're just beginning the process of exploring the *NGSS* or are already far along the path, NSTA has a growing number of tools and resources. Your starting place is the NGSS@NSTA Hub *(www.nsta.org/ngss)*, where you will find our newest materials, including curated resources linked to the standards; a new interactive e-book called *Discover the* NGSS; NSTA Press books on topics such as *Science for All*; and videos to show you what *NGSS* instruction looks like in the classroom.

Check out the official *NGSS* website *(www.nextgenscience.org)* that offers a detailed exploration of the *NGSS* architecture, the Educators Evaluating the Quality of Instructional Products (EQuIP) Rubric, and other resources *(www.nextgenscience.org/resources)*. Also see the NSTA position statement on the *NGSS (www.nsta.org/about/positions/ngss.aspx)*.

As educator Harold Pratt noted in his *NSTA Reader's Guide to the* Next Generation Science Standards: "In rather straightforward terms, the *NGSS* has only two specific purposes beyond its broad vision for science education, namely (1) to describe the essential learning goals, and (2) to describe how those goals will be assessed at each grade level or band. The rest—instruction, instructional materials, assessments, curriculum, professional development, and the university preparation of teachers—is up to the science education community." There is much work ahead, but science teachers everywhere are embracing these exciting changes that are reinvigorating science education. Watch for future articles in this special series on the *NGSS*. ■

Cindy Workosky (cindy_w@nsta.org) *is a communications specialist, and Ted Willard* (twillard@nsta.org) *is director of NGSS@NSTA, at the National Science Teachers Association in Arlington, Virginia.*

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